Summary Report

Item Number 0001AA, Subtask 2.2

Contract Number: N00014-04-C-0189

"Evaluation of Materials for Rapid Runway Repair"

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Summary Report, Subtask 2.2, TASK 2

High Temperature Materials Development/Evaluation Program

Develop products specific to navy application requirements.

In subtask 2.1, materials provided by CeraTech for testing were commercial-off-the-shelf (COTS) and had not been developed to meet specific military requirements. In this task, the contractor shall investigate formulas for improved resistance to high temperature gas effects, yet still meet routine properties such as those listed in Subtask 1.2:

Background

Thermal requirements for specific military applications are focused on the ability of vertical takeoff and landing aircraft (VTOLs) to utilize concrete runways as landing areas. Currently, field conditions require VTOLs to land on steel plate, since the high temperature of the jet wash causes rapid failure and popout of concrete products, and the VTOLs cannot land on soil due to dust and/or ignition of organics.

To date, NFESC has performed preliminary testing of products provided under subtask 2.1, and have preliminarily reported good survivability of the products under cyclic testing using the arc burner test facility at NFESC, Pt. Hueneme.

Despite this success, testing at CeraTech has shown that under extreme elevated temperature conditions, PaveMend products will undergo a significant decrease in strength. In this task, a variety of higher temperature ingredients as well as structural stiffening elements were investigated to attempt to increase the overall strength, particularly under severe thermal loads.

At extreme high temperatures, the mechanism for failure of the PaveMend products involves the loss of bound water, which can be rapidly driven off above water boiling temperatures.

Raw Materials Selection

While the goals of this effort are to improve the strength and thermal resistance characteristics of PaveMend products, ultimate cost will also be kept as a determining factor. The metal oxides currently used in PaveMend products are magnesia/alumina based, but are irregular shaped ground particulates. To add stiffness and additional compressive strength to the product, we will investigate the role of chopped ceramic fibers as low weight % additives to the formula. Specifically, this task will focus on the use of discontinuous aluminum oxide fibers that have been designed to withstand temperatures as high as 1700°C.

ZIRCAR Alumina Bulk Fiber Type ALBF-1 is specially processed aluminum oxide fibers which have relatively short fiber lengths. It is suitable for use in vacuum forming of rigid boards and shapes and as a bulk fill material. It has use at temperatures to 1700°C (3092°F).

ALBF-1 fibers exhibit light weight, low thermal conductivity, low thermal mass and immunity to thermal shock. A minor addition of silica modifies the fiber's microcrystalline structure and act as a grain growth and prevents embrittlement that usually occurs after extended use at elevated temperatures. ALBF-1 resists attack in aggressive chemical environments due to its high purity & refractory nature. It is stable in vacuum, inert or reducing atmospheres.

ALBF-1 fibers and refractory binders yield a uniform body of 0.16 - 0.24 gm/cm3 (10-15 pcf) density, when vacuum formed from a water slurry. Silica, alumina and aluminum phosphate binders can be used to form rigid refractory thermal insulation products.

ALBF-1 fiber is useful as insulation packing in furnace spaces, around furnace sight tubes & ports and fill in expansion joints and masonry cracks.

ALBF-1 offers significant advantages over vitreous alumino-silicate fibers, including:

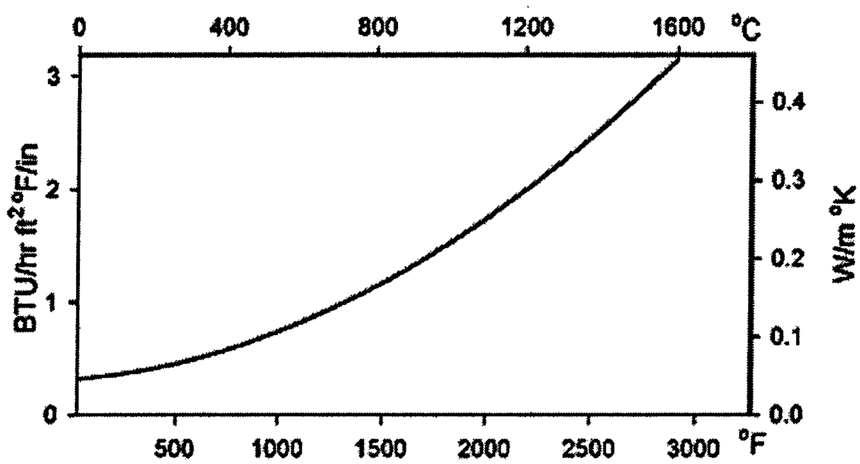
- High temperature dimensional stability
- Resilience and flexibility after exposure to elevated temperatures
- Exceptional refractoriness

Specific propertie of ALBF – 1 are presented in Table 1.

Table 1. Characteristics and Properties

Composition, %	
Al_2O_3	97
SiO_2	3
Organics	0
Alpha Alumina, wt%	>50
Color	White
Density, gm/cc (pcf)	3.4 (212)
Fiber Length, mean mm (in)	3.2 (.125)
Mean Diameter, microns	3
Maximum Use Temp.*, °C (°F)	1700 (3092)
Melting Point, °C (°F)	2038 (3700)
Specific Heat, J/kg °K (BTU/lb °F)	1047 (0.25)
Shot Content	Nil
Shipping Density, gm/cc (pcf)	0.1 (6)
Packed Density Range, gm/cc (pcf)	0.1 - 0.19 (6-12)
Linear Shrinkage, %	
1 hr at 1538°C (2800°F)	2
1 hr at 1650°C (3002°F)	4

Thermal Conductivity at 6 pcf packed density



Test Approach

Ceratech does not have the ability to reproduce jet thermal signatures in house. Our approach to this effort is to exceed the thermal energy requirements imparted by the NFESC facility, and then measure the benefits of the formula modifications as a qualitative assessment.

For these studies, the Pavemned 15.0 product was selected. It was modified with 1 and 2 weight percent of the Zircar ALBF-1 high temperature fibers. These amounts placed in a 45 pound bucket of PaveMend 15.0 result in additions of 0.45 and 0.90 pounds, respectively, of the Zircar fiber additions. Testing showed that going beyond this level resulted in clumping/agglomeration of the fibers. This effect would be a detriment to the overall strength of the fully cured product. After the addition of the fibers to the formula, the product was then dry tumbled for 15 minutes to insure thorough mixing of the fibers with the other ingredients.

Cubes of these products were poured (2 inch on edge). The cubes were allowed to cure for 14 days. At this point in time, the PaveMend 15.0 formula is at approximately 80% of its ultimate compressive strength at 28 days.

At this point, the cubes were then subjected to three different thermal cycles. The first was a thirty-minute soak in a muffle furnace at a temperature of 1000°F. The second series also at 1000°F was for a duration of one-hour. The third exposure was 5 minutes at 1000°F, followed by a 5 minute ambient quench. This cycle was repeated 5 times. The cubes were then allowed to quench back to ambient temperatures (70°F) and tested to compressive failure. Results are shown in the following section.

Test Data

The following materials were fabricated:

- base formula PaveMend 15.0
- PaveMend 15.0 + 1% Zircar Alumina fiber, type ALBF

- PaveMend 15.0 + 2% Zircar Alumina fiber, type ALBF

Higher than 2% resulted in a non-flowing cement mix, therefore the testing was stopped at the 2% loading level.

Data from the test series is presented in Table 2.

Table 2.

Thermal Treatment	**Avg. Cube weight**			**Avg. Compressive Strength (psi)/ (% improvement over base)**		
	Base	**1% fiber**	**2% fiber**	**Base**	**1% fiber**	**2% fiber**
NONE	263	262	264	4911	5540/(13)	5570/(13)
1000F, 30 min	221	220	219	515	675/(31)	790/(53)
1000F, 60 min	218	219	220	420	585/(39)	640/(52)
1000F, 5 min exp, 10 min cool; 5 cycles	223	218	221	450	643/(43)	782/(74)

Conclusions and Recommendations

It should be stated up front that the test conditions applied by CeraTech are extreme. Specifically, we have subjected a fixed small volume of PaveMend material to a very high temperature environment for a long dwell time. Under these conditions, the weekly bound water in the phosphate materials is driven off, as is evidenced by the loss of weight shown in Table 2. This loss of water is breaking bonds that form in the phosphate cement and the resulting loss of strength is evident in the data. However, the base materials tested in this subtask have already undergone extensive cyclic testing at NFESC, and have shown good dimensional stability, no cracking, and good bond to the substrate concrete. The differences in the test methods are significant, and show that, in the NFESC field application test approach, the PaveMend product behaves adequately to work with VTOLs.

In the new data generated by Ceratech, we have shown that the base materials, plus small additions of ceramic fibers exhibit a significant % strength increase over base product when exposed to extreme high temp conditions. These increases in strength would translate into a superior strength product for airfield applications where high temperature exhaust will be a factor.

Samples of these products will be provided to NFESC for their independent evaluation under Subtask 2.3. Per the requirements of subtask 2.3, CeraTech is to assist with the training at

NFESC. However, all necessary training has been provided and the new fiber modified variant of PaveMend will mix/behave just like commercial PaveMend 15.0 during mixing and placement. Per subtask 2.3, the redesigned CeraTech products will be tested by NFESC using the High Temperature Jet Exhaust Simulation Facility (HTJESF) calibrated for AV-8B exhaust. With the materials provided by Ceratech in subtask 2.3, HFESC will fabricate 24 inch diameter specimens in which the PaveMend product is applied as a 2 inch think overlay on Portland Cement concrete, such as the sample shown in Figure 1. These samples will be subjected the AV-8B thermal pulse and then placed in a refrigerator to simulate the thermal shock conditions encountered by runway surfaces under severe cold weather conditions.

Figure 1.